Appendix M
Dosimetry-related Guidance

Part 1:
Guidance for Demonstrating that Unmonitored Individuals are Not Likely to Exceed 10 Percent of the Allowable Limits

Dosimetry is required for individuals likely to receive, in 1 year from sources external to the body, a dose in excess of 10% of the applicable regulatory limits in 180 NAC 4-005. To demonstrate that dosimetry is *not* required, a licensee needs to have available, for inspection, an evaluation to demonstrate that its workers are not likely to exceed 10% of the applicable annual limits.

The most common way that individuals *might* exceed 10% of the applicable limits is by performing frequent routine cleaning and lubrication of gauges. Thus, a licensee would need to evaluate the doses its workers might receive in performing these tasks to assess whether dosimetry is required.

Example

One gauge manufacturer has estimated the doses to the extremities and whole body of a person replacing the assay plate on one of its series of gauges. Each gauge in the series is authorized to contain up to 7.4 gigabecquerels (200 millicuries) of Cs-137. The manufacturer based its estimate on observations of individuals performing the recommended procedure according to good radiation safety practices. The manufacturer had the following types of information:

- Time needed to perform the entire procedure (e.g., 15 minutes)
- Expected dose rate received by the whole body of the individual, associated with the shielded source and determined using measured or manufacturer-determined data (e.g., 0.02 mSv/hr [2 mrem/hr] at 46 cm [18.1 in] from the shield)
- Time the hands were exposed to the shielded source (e.g., 6 min)
- Expected dose rate received by the extremities of the individual, associated with the shielded source and determined using measured or manufacturer-determined data on contact with the shield (e.g., 0.15 mSv/hr [15 mrem/hr])

From this information, the manufacturer estimated that the individual performing each routine cleaning and lubrication could receive the following:

- Less than 0.005 mSv (0.5 mrem) TEDE (whole body) and
- 0.015 mSv (1.5 mrem) to the hands.

The applicable TEDE (whole body) limit is 50 mSv (5 rems) per year and 10% of that value is 5 mSv (500 millirems) per year. If one of these procedures delivers 0.005 mSv (0.5 mrem), then an individual could perform 1,000 of these procedures each year and remain within 10% of the applicable limit.

The applicable shallow-dose equivalent (SDE) (extremities) is 500 mSv (50 rems) is 500 mSv (50 rems) per year and 10% of that value is 50 mSv (5 rems or 5000 millirems) per year. If one of these procedures delivers 0.015 mSv (1.5 mrem), then an individual could perform 3,333 of these procedures each year and remain within 10% of the applicable limit.

Based on the above specific situation, no dosimetry is required if a worker performs fewer than 1,000 routine maintenance procedures per year.

GUIDANCE TO LICENSEES

Licensees who wish to demonstrate that they are not required to provide dosimetry to their workers need to perform prospective evaluations similar to that shown in the example above. The expected dose rates, times, and distances used in the above example may not be appropriate to individual licensee situations. In their evaluations, licensees need to use information appropriate to the type(s) of gauge(s) they intend to use; this information is generally available from the gauge manufacturer or the SSD Registration Certificate maintained by the NRC and Agreement States.

Table M1-1 may be helpful in performing a prospective evaluation.

Licensees should review evaluations periodically and revise them as needed. Licensees need to check assumptions used in their evaluations to ensure that they continue to be up-to-date and accurate. For example, if workers become lax in following good radiation safety practices, perform the task more slowly than estimated, work with new gauges containing sources of different activities or radionuclides, or use modified procedures, the licensee would need to conduct a new evaluation.

Table M1-1, Dosimetry Evaluation

Dosimetry Evaluation for _____ Model _____ Fixed Gauge			
A.	Time needed to perform the entire routine cleaning and lubrication procedure on the gauge	_____minutes/60	_____hour
B.	Expected whole body dose rate received by the individual, determined using exposure rates measured on contact with the gauge while the sealed source is in the shielded position.		_____mrem/hr
C.	Time the <u>hands</u> were exposed to the unshielded source	_____minutes/60	_____hour
D.	Expected extremity dose rate which the individual will encounter, determined using measured or manufacturer-provided data for the unshielded source at the typical distance from the hands to the unshielded source.		_____mrem/hr
Formula: (_____#hours in Row A) x (_____mrem/hr in Row B) = (_____estimated mrem) x (_____# of clean and lubrications conducted each year) = _____ mrem *Whole Body Dose Equivalent			
Formula: (_____#hours in Row C) x (_____mrem/hr in Row D) = (_____estimated mrem) x (_____# of clean and lubrications conducted each year) = _____ mrem **Extremity Dose Equivalent			
*Whole Body Dose Equivalent ***less than*** 500 mrem requires no dosimetry **Extemity Dose Equivalent ***less than*** 5000 mrem requires no dosimetry			

Appendix M, Part 2

Guidance for Demonstrating that Individual Members of the Public will not Receive Doses Exceeding the Allowable Limits

Appendix M, Part 2
Guidance for Demonstrating that Individual Members of the Public will not Receive Doses Exceeding the Allowable Limits

Licensees must ensure that:

- The radiation dose received by individual members of the public does not exceed 1 millisievert (1 mSv) [100 millirems (100 mrem)] in one calendar year resulting from the licensee's possession and/or use of radioactive materials.

Members of the public include persons who live, work, or may be near locations where fixed gauges are used or stored and employees whose assigned duties do not include the use of radioactive materials and who work in the vicinity where gauges are used or stored.

- The radiation dose in unrestricted areas does not exceed 0.02 mSv (2 mrem) in any one hour.

Typical unrestricted areas may include offices, shops, laboratories, areas outside buildings, property, and nonradioactive equipment storage areas. The licensee does not control access to these areas for purposes of controlling exposure to radiation or radioactive materials. However, the licensee may control access to these areas for other reasons such as security**.**

Licensees must show compliance with both portions of the regulation. Calculations or a combination of calculations and measurements (e.g., using an environmental TLD) are often used to prove compliance.

CALCULATIONAL METHOD

For ease of use by most fixed gauge licensees, the examples in this Appendix use conventional units. The conversions to SI units are as follows: 1 ft = 0.305 m; 1 mrem = 0.01 mSv.
The calculational method takes a tiered approach, going through a three-part process starting with a worst case situation and moving toward more realistic situations. It makes the following simplifications:

- each gauge is a point source;
- typical radiation levels encountered when the source is in the shielded position are taken from either the Sealed Source & Device (SSD) Registration Certificate or the manufacturer's literature; and
- no credit is taken for any shielding found between the gauges and the unrestricted areas.

Part 1 of the calculational method is simple but conservative. It assumes that an affected member of the public is present 24 hours a day and uses only the inverse square law to determine if the distance between the gauge and the affected member of the public is sufficient to show compliance with the public dose limits. Part 2 considers not only distance, but also the time that the affected member of the public is actually in the area under consideration. Part 3 considers distance and the portion of time that both the gauge and the affected member of the public are present. Using this approach, licensees make only those calculations that are needed to demonstrate compliance. In many cases licensees will need to use the calculational method

through Part 1 or Part 2. The results of these calculations typically result in higher radiation levels than would exist at typical facilities, but provide a method for estimating conservative doses which could be received.

Example 1

To better understand the calculational method, we will look at ABC Bottling, Inc., a fixed gauge licensee. Yesterday, while on a walk-through during product changeover, the company's president noted that three new gauges will be very close to a bottling control panel where a quality control supervisor, a worker who does not work with fixed gauges, works. The company's president asked Joe, the Radiation Safety Officer (RSO), to determine if the company is complying with Agency's regulations.

Joe measures the distances from each gauge to the bottling control panel and looks up in the manufacturer's literature the radiation levels individuals would encounter for each gauge. Figure M1 is Joe's sketch of the areas in question, and Table M2-1 summarizes the information Joe has on each gauge.

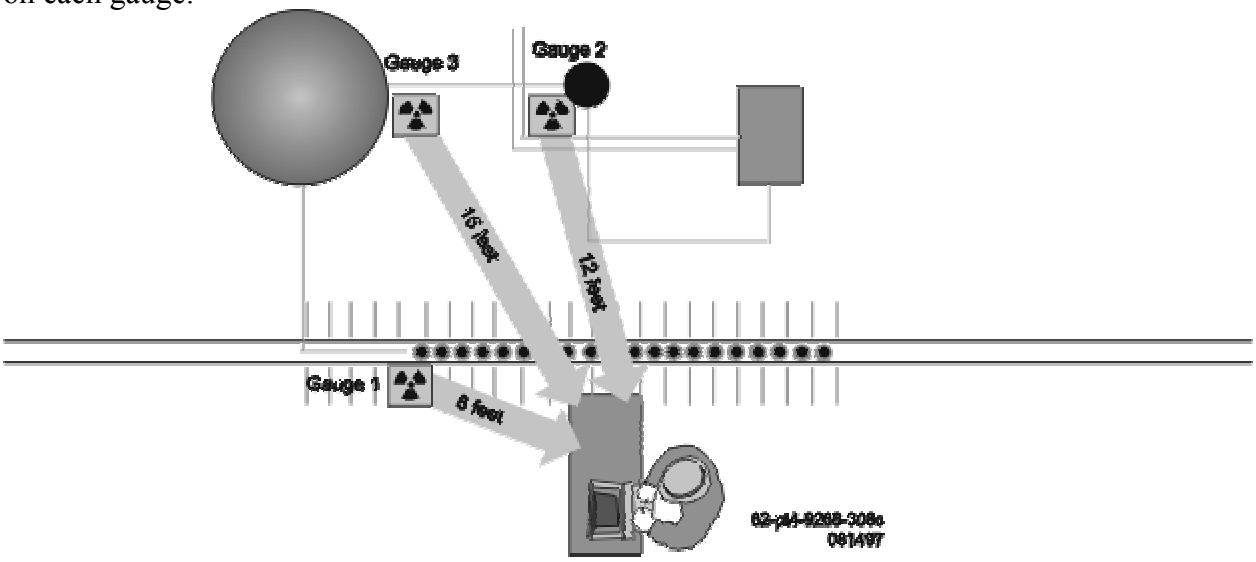

Figure M1: **Diagram of Bottling Line and Fixed Gauges. This sketch shows the areas described in Examples 1 and 2.**

Table M2-1, Information Known about Each Gauge

DESCRIPTION OF KNOWN INFORMATION	GAUGE 1	GAUGE 2	GAUGE 3
How gauge is located	Gauge on bottling line	Gauge on main feed line	Gauge on tank
Dose rate in mrem/hr encountered at specified distance from the gauge (from manufacturer's literature)	2 mrem/hr at 1 ft	8 mrem/hr at 1 ft	2 mrem/hr at 3 ft
Distance in ft to secretary's chair	8 ft	12 ft	15 ft

Example 1: Part 1

Joe's first thought is that the distance between the gauges and the bottling control panel may be sufficient to show compliance with the regulation in 180 NAC 4-013. So, taking a worst case approach, he assumes: 1) the gauges are constantly present (i.e., 24 hr/d), 2) all three gauges are on (i.e., shutters are open), and 3) a quality control (QC) supervisor, a worker who does not work with the fixed gauges, is constantly sitting at the control panel (i.e., 24 hr/d). Joe proceeds to calculate the dose the QC supervisor might receive hourly and yearly from each gauge as shown in Tables M2-2, M2-3, and M2-4 below.

Table M2-2, Calculational Method, Part 1---Hourly and Annual Dose Received from Gauge 1

		GAUGE 1	
Step No.	**Description**	**Input Data**	**Results**
1	Dose received in an hour at known distance from gauge (e.g., from manufacturer's data), in mrem/hr	2	2
2	Square of the distance (ft) at which the Step 1 rate was measured, in ft^2	$(1)^2$	1
3	Square of the distance (ft) from the gauge to the bottling control panel in an unrestricted area, in ft^2	$(8)^2$	64
4	Multiply the results of Step 1 by the results of Step 2 (this is an intermediate result)	2 x 1 =2	
5	Divide the result of Step 4 by the result of Step 3 to calculate the dose received by the worker at the bottling control panel**, HOURLY DOSE RECEIVED FROM GAUGE 1**, in mrem in an hour.	2/64 = **0.031**	
6	Multiply the result of Step 5 by 24 hr/d x 365 d/yr = **MAXIMUM ANNUAL DOSE RECEIVED FROM GAUGE 1**, in mrem in a year.	0.031 x 24 x 365 = 0.031 x 8760 = **272**	

Table M2-3, Calculational Method, Part 1---Hourly and Annual Dose Received from Gauge 2

		GAUGE 2	
Step No.	**Description**	**Input Data**	**Results**
1	Dose received in an hour at known distance from gauge (e.g., from manufacturer's data), in mrem/hr	8	8
2	Square of the distance (ft) at which the Step 1 rate was measured, in ft^2	$(1)^2$	1
3	Square of the distance (ft) from the gauge to the bottling control panel in an unrestricted area, in ft^2	$(12)^2$	144
4	Multiply the results of Step 1 by the results of Step 2 (this is an intermediate result)	8 x 1 = 8	
5	Divide the result of Step 4 by the result of Step 3 to calculate dose received in an hour by worker at the bottling control panel**, HOURLY DOSE RECEIVED FROM GAUGE 2**, in mrem in an hour	8/144 = **.056**	
6	Multiply the result of Step 5 by 24 hr/d x 365 d/yr = **MAXIMUM ANNUAL DOSE RECEIVED FROM GAUGE 2**, in mrem in a year	0.056 x 24 x 365 =0.056 x 8760 = **491**	

Table M2-4, Calculational Method, Part 1---Hourly and Annual Dose Received from Gauge 3

		GAUGE 3	
Step No.	**Description**	**Input Data**	**Results**
1	Dose received in an hour at known distance from gauge (e.g., from manufacturer's data), in mrem/hr	2	2
2	Square of the distance (ft) at which the Step 1 rate was measured, in ft^2	$(3)^2$	9
3	Square of the distance (ft) from the gauge to bottling control panel in a unrestricted area, in ft^2	$(15)^2$	225
4	Multiply the results of Step 1 by the results of Step 2 (this is an intermediate result)	2 x 9 =18	
5	Divide the result of Step 4 by the result of Step 3 to calculate dose received by a worker at the bottling control panel, **HOURLY DOSE RECEIVED FROM GAUGE 3**, in mrem in an hour	18/225 = **0.08**	
6	Multiply the result of Step 5 by 24 hr/d x 365 d/yr = **MAXIMUM ANNUAL DOSE RECEIVED FROM GAUGE 3**, in mrem in a year	0.08 x 24 x 365 = 0.08 x 8760 = **701**	

To determine the total hourly and total annual dose received, Joe adds the pertinent data from the preceding tables.

Table M2-5, Calculational Method, Part 1---Total Hourly and Annual Dose Received from Gauges 1, 2, and 3

Step No.	Description	Gauge 1	Gauge 2	Gauge 3	Sum
7	**TOTAL HOURLY DOSE RECEIVED** from Step 5 of Tables M2-3, M2-4, and M2-5, in mrem in an hour	0.031	0.056	0.08	0.031 + 0.056 + 0.08 = **0.167**
8	**TOTAL ANNUAL DOSE RECEIVED** from Step 6 of Tables M2-3, M2-4, and M2-5, in mrem in a year	272	491	701	272 + 491 + 701 = **1464**

NOTE: **The Sum in Step 7 demonstrates compliance with the 2 mrem in any one hour limit. Reevaluate if assumptions change. If the Sum in Step 8 exceeds 100 mrem/yr, proceed to Part 2 of the calculational method.**

At this point, Joe is pleased to see that the total dose that an individual could receive in any one hour is only 0.167 mrem, but notes that an individual could receive a dose of 1,464 mrem in a year, much higher than the 100 mrem limit.

Example 1: Part 2

Joe reviews his assumptions and recognizes that the QC supervisor is not at the bottling control panel 24 hr/d. He decides to make a realistic estimate of the number of hours the QC supervisor would be present at the bottling control panel, keeping his other assumptions constant (i.e., the gauges are constantly present (i.e., 24 hr/d), all three gauges remain on (i.e., shutter is open). He then recalculates the annual dose received.

Table M2-6, Calculational Method, Part 2---Annual Dose Received from Gauges 1, 2, and 3

Step No.	Description	Results
9	A. Average number of hours per day that individual spends in area of concern (e.g., worker present at bottling control panel 5 hr/day; the remainder of the day the worker is away from the area performing other duties that are not in the vicinity of gauges) B. Average number of days per week in area (e.g., worker is part time and works 3 days/week) C. Average number of weeks per year in area (e.g., worker works all year)	5 3 52
10	Multiply the results of Step 9.A. by the results of Step 9.B. by the results of Step 9.C. = **AVERAGE NUMBER OF HOURS IN AREA OF CONCERN PER YEAR**	5 x 3 x 52 = **780**
11	Multiply the sum in Step 7 by the results of Step 10 = **ANNUAL DOSE RECEIVED FROM GAUGES CONSIDERING REALISTIC ESTIMATE OF TIME SPENT IN AREA OF CONCERN**, in mrem in a year	0.167 x 780 = **130**

NOTE: **If Step 11 exceeds 100 mrem in a year, proceed to Part 3 of the calculational method.**

Although Joe is pleased to note that the calculated annual dose received is significantly lower, he realizes it still exceeds the 100 mrem in a year limit.

Example 1, Part 3

Again Joe reviews his assumptions and recognizes that Gauge 3 will only be used on the process line during product changeovers and Gauge 2 has different radiation levels depending on whether the gauge is in the on or off position (i.e., shutter is open or closed). As he examines the situation, he realizes he must consider each gauge individually.

Table M2-7, Calculational Method, Part 3---Summary of Information

INFORMATION ON WHEN GAUGES ARE PRESENT IN THE STORAGE AREA:

- **Gauge 1:** operates continuously (24 hrs/day) on the bottling line.
- **Gauge 2:** operates (in the "on" position) while the tank is being filled, approximately 1 hour during the time the worker is present. When the pipe is not filling the tank, the gauge is in the "off" position. While in the "off" position, the radiation level around the gauge drops to 2 mrem/hr at 1ft, one-fourth of the radiation level as when the gauge is in the "on" position.
- **Gauge 3:** is only used on the process line during product changeovers, 4 weeks per year. While affixed, it operates continuously (24 hrs/day).

INFORMATION FROM EXAMPLE 1, PART 2, ON WHEN THE WORKER IS PRESENT AT THE BOTTLING CONTROL PANEL:

- 5 hours per day
- 3 days per week
- 52 weeks per year

Table M2-8, Calculational Method, Part 3---Annual Dose Received from Gauges 1, 2, and 3

Step No.	Description	GAUGE 1	GAUGE 2 "ON'	GAUGE 2 "OFF"	GAUGE 3
12	Average number of **hours per day** gauge operates when worker is present at the bottling control panel	**5**	**1**	**5**	**5**
13	Average number of **days per week** gauge operates when worker is present at the bottling control	**3**	**3**	**3**	**3**
14	Average number of **weeks per year** gauge operates when worker is present at the bottling control	**52**	**52**	**32**	**4**
15	Multiply the results of Step 12 by the results of Step 13 by the results of Step 14 = **TOTAL hours each gauge operates when worker is present at the bottling control panel**	5 x 3 x 52 = **780**	1 x 3 x 52 = **156**	4 x 3 x 52 = **624**	5 x 3 x 4 = **312**
16	Multiply the results of Step 15 by the results of Step 7 = **ANNUAL DOSE RECEIVED FROM EACH GAUGE**, in mrem in a year	780 x 0.031 = **24**	156 x 0.056= **8.7**	624 x (0.056/4) = **8.7**	312 x 0.08 = **4.8 in mrem in a year**

17	Sum the results of Step 16 for each gauge = **TOTAL ANNUAL DOSE RECEIVED CONSIDERING REALISTIC ESTIMATE OF TIME SPENT IN AREA OF CONCERN AND TIME GAUGE IS OPERATES**, in	24 + 8.7 + 8.7 + 4.8 = **46.2**

NOTE: **If the result in Step 17 is greater than 100 mrem/yr, the licensee must take corrective actions.**

Joe is pleased that the result in Step 17 shows compliance with the 100 mrem/yr limit. Had the result in Step 17 been higher than 100 mrem/yr, then Joe could have done one or more of the following:

- Consider whether the assumptions used to determine occupancy and the time each gauge operates are accurate, revise the assumptions as needed, and recalculate using the new assumptions
- Calculate the effect of any shielding located between the gauges and the bottling control panel -- such calculation is beyond the scope of this Appendix
- Take corrective action (e.g., add shielding, move the bottling control panel) and perform new calculations to demonstrate compliance
- Train the QC supervisor as required by 180 NAC 10-003.

Note that in the example, Joe evaluated the unrestricted area at the bottling control panel. Licensees also need to make similar evaluations for other unrestricted areas and to keep in mind the ALARA principle, taking reasonable steps to keep radiation dose received below regulatory requirements. In addition, licensees need to be alert to changes in situations (e.g., adding a gauge to the process line, changing the QC supervisor's schedule, or changing the estimate of the portion of time spent at the bottling control panel) and to perform additional evaluations, as needed.

RECORD KEEPING: 180 NAC 4-053 requires licensees to maintain records demonstrating compliance with the dose limits for individual members of the public.

Combination Measurement - Calculational Method

This method, which allows the licensee to take credit for shielding between the gauge and the area in question, begins by measuring radiation levels in the areas, as opposed to using manufacturer-supplied rates at a specified distance from each gauge. These measurements must be made with calibrated survey meters sufficiently sensitive to measure background levels of radiation. A maximum dose of 1 mSv (100 mrem) received by an individual over a period of 2080 hours (i.e., a work year of 40 hr/wk for 52 wk/yr) is equal to less than 0.5 microsievert (0.05 mrem) per hour.

This rate is well below the minimum sensitivity of most commonly available G-M survey instruments.

Instruments used to make measurements for calculations must be sufficiently sensitive. An instrument equipped with a scintillation-type detector (e.g., NaI(Tl)) or a micro-R meter used in making very low gamma radiation measurements should be adequate.

Licensees may also choose to use environmental TLDs. TLDs used for personnel monitoring (e.g., LiF) may not have sufficient sensitivity for this purpose. Generally, the minimum reportable dose received is 0.1 mSv (10 mrem). Suppose a TLD monitors dose received and is changed once a month. If the measurements are at the minimum reportable level, the annual dose received could have been about 1.2 mSv (120 mrem), a value in excess of the 1 mSv/yr (100 rem/yr) limit. If licensees use TLDs to evaluate compliance with the public dose limits, they should consult with their TLD supplier and choose more sensitive TLDs, such as those containing CaF2 that are used for environmental monitoring. This direct measurement method would provide a definitive measurement of actual radiation levels in unrestricted areas without any restrictive assumptions. Records of these measurements can then be evaluated to ensure that rates in unrestricted areas do not exceed the 1 mSv/yr (100 mrem/yr) limit.

Example 2

As in Example 1, Joe is the RSO for ABC Bottling, Inc., a fixed gauge licensee. The company has three gauges located near a bottling control panel which is operated by a worker who does not work with the fixed gauges. See Figure M-1 and Table M2-1 for information. Joe wants to see if the company complies with the public dose limits at the bottling control panel.

Joe placed an environmental TLD badge at the bottling control panel for 30 days. The TLD processor sent Joe a report indicating the TLD received 100 mrem.

Table M2-10, Combination Measurement-Calculational Method

Step No.	Description	Input Data and Results
	PART 1	
1	**Dose** received by ***TLD***, in mrem	**100**
2	**Total hours *TLD*** exposed	24 hr/d x 30 d/mo = **720**
3	Divide the results of Step 1 by the results of Step 2 to determine **HOURLY DOSE RECEIVED**, in mrem in an hour	**0.14**
4	Multiply the results of Step 3 by 365 d/yr x 24 hr/d = 8760 hours in one year = **MAXIMUM ANNUAL DOSE RECEIVED FROM GAUGES**, in mrem in a year	365 x 24 x 0.14 = 8760 x 0.14 = **1226**
	NOTE: **For the conditions described above, Step 3 indicates that the dose received in any one hour is less than the 2 mrem in any one hour limit. However, if there are any changes, then the licensee would need to reevaluate the potential doses which could be received in any one hour. Step 4 indicates that the annual dose received would be much greater than the 100 mrem in a year allowed by the regulations.**	
	PART 2	
	At this point Joe can adjust for a realistic estimate of the time the worker spends at the bottling control panel as he did in Part 2 of Example 1.	
	PART 3	
	If the results of Joe's evaluation in Part 2 show that the annual dose received in a year exceeds 100 mrem, then he can make adjustments for realistic estimates of the time spent in the area of concern as in Part 3 of Example 1. (Recall that the TLD measurement was made while all the gauges were operating; i.e., 24 hr/d for the 30 days that the TLD was in place.)	